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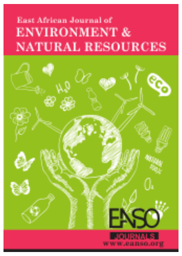

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Original Article

More Trees and More Biomass Energy Options for Increased Energy Security within Households in Navakholo Sub-County, Kenya

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ABSTRACT

To date, most rural households in Navakholo constituency rely on wood fuel for domestic energy requirements, especially cooking. The increasing population is putting a lot of pressure on tree cover, its role in climate change mitigation and biodiversity conservation notwithstanding. Switching to energy alternatives within the biomass domain presents a policy option to increase access to household energy. This paper reports on the emerging trends in this regard. Spatial survey was used to track land use and tree cover changes from 1990-2022. A questionnaire survey was used to collect data from a sample size of 395 respondents selected through systematic random sampling. A majority (78.9%) of the respondents indicated having adequate (covering over 10% of the land) tree cover, with woodlots accounting for 39.8% and trees planted along fences at 37.3%. Nevertheless, 43.4% of the households indicated that the fuelwood supply was not able to meet household energy demand. Chi-square analysis indicated that there was a significant relationship between household biomass usage, tree density and adequacy of fuel wood in the area (p = .004 and p = .004), indicating that firewood remains the choice energy source despite the apparent diminishing tree cover. This paper calls for the need to increase tree cover and access to alternative biomass options.

APA CITATION

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INTRODUCTION

Biomass has been used over the years as a source of energy for households, particularly in developing countries (Mugo & Gathui, 2010). Africa consumes more renewables than any other energy source mainly due to the high use of traditional biomass resources in the continent (World Bioenergy Association, 2018). Biomass is currently the most widespread form of renewable energy and its exploitation is increasing due to concerns over the devastating impacts of fossil fuel and environmental and health concerns associated with other forms of energy (Tursi, 2019). Reliance on firewood for cooking is still popular, largely due to the inability to afford cleaner energy sources like electricity (IEA, 2010; Belward *et al*., 2011). As compared to the use of agricultural residues, which are generally regarded as free, high prices of fuel wood at Kshs 800- 1200 per 0.65m^3 of wood have exerted pressure on households (Ndegwa, 2010). Biomass is also a popular option due to the little capital that is needed to use the resource. Traditional cookstoves (three stones) are typically what is used for cooking. This is hardly capital-intensive as compared to other sources of fuel. Biomass use is closely intertwined with poverty, and the energy poverty line begins to rise with higher income (The World Bank, 2011; Diaz-Chavez *et al.*, 2015).

Biomass fuels are the largest source of primary energy in Kenya with wood fuel (firewood and charcoal) accounting for about 69% of the total primary energy consumption and 90% of rural household energy needs. About 55% of this is derived from farmlands in the form of woody biomass as well as crop residue and animal waste, and the remaining 45% is derived from forests (Government of Kenya, 2015). Government ministries are supporting the sustainable production of energy crops and the dissemination of improved cook stoves. Despite the fact that biomass dominates the energy landscape, little or no budget is provided for research and development

The residential sector holds the majority of the energy consumption in Kakamega. Main activities include cooking, whose main energy source is solid biomass (firewood and charcoal). Firewood is self-collected, which implies no monetary cost but a very low heating value. The average household consumption is 6.8 kg ((Korkovelos, 2015). Charcoal consumption is higher in regions with increased income. The average household consumption of charcoal per year is about 750 kg, translating to 62.5 Kg per month and 2 kg per day. In Kakamega County, fuels used in the household include firewood at 86.8%, charcoal at 8.9%, kerosene/paraffin at 2.3%, LPG at 0.8%, electricity at 0.5%, Biogas at 0.4% and other energy sources at 0.3% (Ngugi et al., 2013). Both firewood and charcoal consumption depend on the cook stove utilised and its efficiency.

Studies show a positive relationship between population growth rates and energy demand (Kabede *et al*., 2010). The increasing population will lead to an increased demand for energy resources and will eventually affect the availability of biomass within households. According to the

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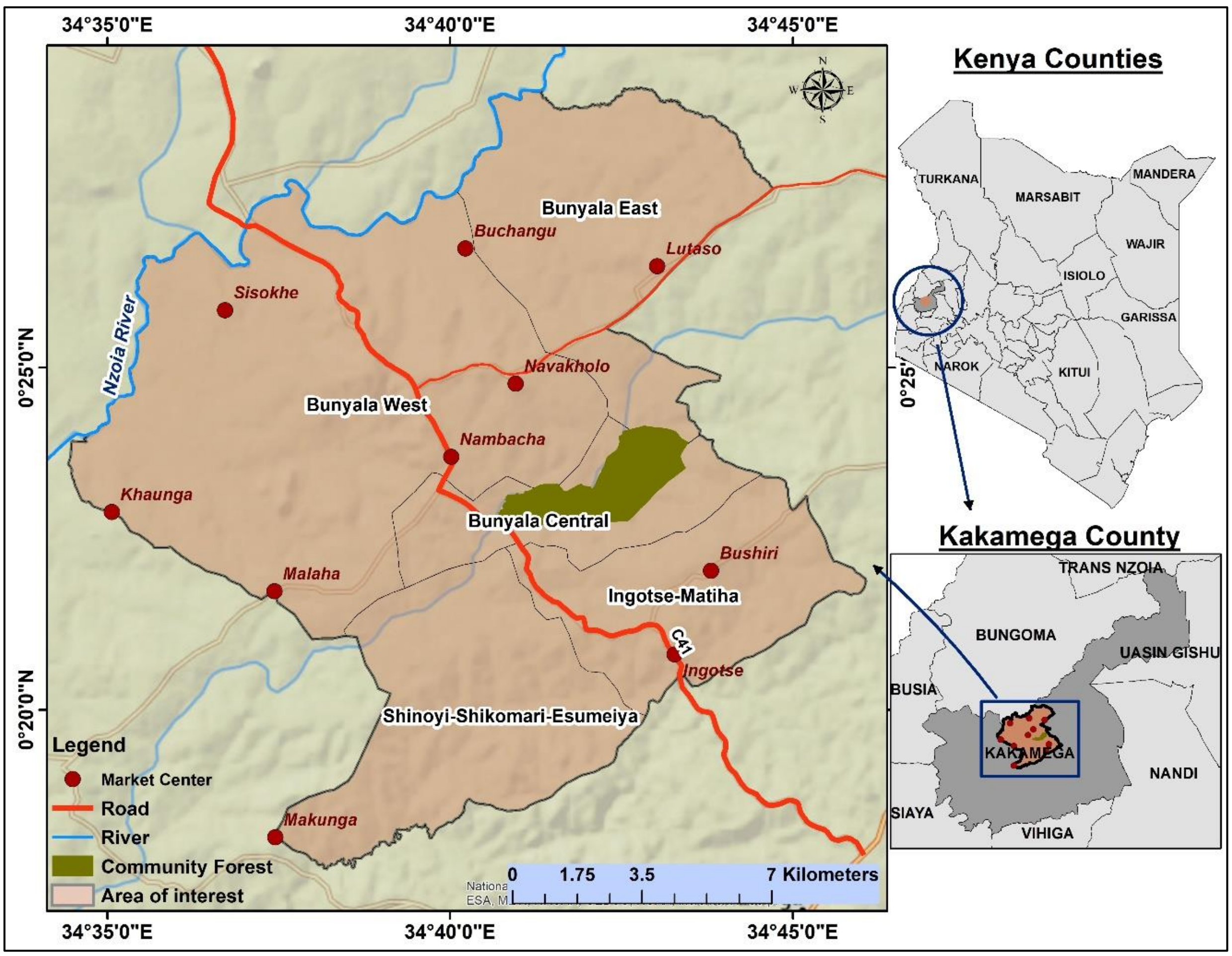
Ministry of Energy (2018), 70% of rural households rely on biomass for their energy needs. This is because it is an affordable and available source of fuel as it is easily found practically anywhere. The dependence on biomass is also partially attributed to poor access to electricity (Lusambo, 2016). The study addresses the relationship between tree cover and access to biomass. It addresses whether tree cover has an impact on the availability of biomass in the households and how households can sustainably manage trees. The study will have an impact on the use of biomass in relation to the available tree cover. Households will benefit in terms of having adequate tree cover and at the same time having adequate access to biomass.

MATERIALS AND METHODS

Study Site

Figure 1: Location of the study area



Source: Esri Eastern Africa, Garmin, National Geographic

This study was carried out in Navakholo Sub-County in Kakamega County (*Figure 1*). Its estimated population based on the 2019 national census is 153,977 (Government of Kenya, 2019). The five sub counties constituted the research sites, thus: Bunyala West, Bunyala East, Bunyala Central, Ingotse-Matiha, and Shinoyi-Shikomari-Esumeiya. The popular food crops grown include maize, sorghum, beans, and cassava. Expansion of sugarcane in the past was responsible for significant loss of tree cover and also agrobiodiversity. Study Design

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The study adopted a mixed methods research design. This is an approach to inquiry that combines both qualitative and quantitative approaches (mixed methods research design), as used by Mutuku (2020). The qualitative approaches focused on investigations on tree cover and land use changes from the period covering 1990-2020 and household characteristics influencing accessibility and availability of biomass within Navakholo Sub-County. The qualitative approach involved investigations into perceptions of land use changes over the years. Quantitative methods were used to test for relationships between variables in the results. The use of both methods ensures that the overall strength of the study is greater than either qualitative or quantitative research.

Spatial design using GIS procedures was used to track land use and changes in tree cover being the main environment descriptor. Ground truthing necessitated the use of transect surveys and environmental checklists to document the observed status of the land. Standard Geographical Information System (GIS) procedures were used to map out the study area and to assess land use and cover trends from 1990-2020. Satellite images covering the years 1990, 1995, 2000, 2005, 2010, 2015 and 2020 were obtained from Landsat 8, 7 and 1-5. This was done through a ground survey, where GPS coordinates were recorded and photographs were taken. Secondary GIS data was used. Satellite images were processed and classified. These images were then subjected to accuracy assessment using programmes like google earth to produce the land cover maps.

Target Population and Samples Size

Table 1: Distribution of respondents in wards in Navakholo sub-county

Ward Name	Population	Area in km^2	Weighted pop. ratio	Percentage of Respondents	Proportionate sample size
Ingotse-Matiha	22,091	34.4	1	16.1	52
Shinoyi-Shikomari-Esumeiya	25,352	48.4	1.4	18.5	74
Bunyala West	38,407	73.3	2.1	28	111
Bunyala East	22,122	45.1	1.3	16.1	68
Bunyala Central	29,193	56.8	1.7	21.3	90
Total	137165	228	7.5	100	395

From a target population of 32,315 households (Government of Kenya, 2019), a sample size of 395 respondents was calculated based on the formula by Yamane (1967) and Israel (2003) and allocated to the wards proportionately (*Table 1*).

Focus Group discussions (FGDs) targeted ten people in each ward, composed of men, women, and youth, to get a unique perspective of their interaction with biomass. Discussions were done to address emerging issues from the questionnaire survey. Consensus built on each key item was presented as a narrative to support the discussion of results.

Statistical Methods

Questionnaire data obtained from the 395 respondents were analysed for descriptive and inferential statistics. Correlation analysis was used to quantify the direction and strength of associations between selected variables. Cross tabulations were also used to compare the relationships between various variables. The chi-square statistic was used to assess the relationship between selected pairs of variables key to the study. An environmental checklist was used to document the status of tree coverage, species, and biomass use in households.

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RESULTS AND DISCUSSION

Status of Tree cover in Navakholo

The year 1990 served as a baseline year from which land cover changes were measured. Area computation shows that 5689.78 hectares were covered by woodland vegetation. (*Figure 2*). There was a slight decline in the area covered by woodland from 1995 to 2000, from 5195.77 ha to 5012.92 ha (*Figure 3*, *Table 2*). This was attributed to encroachment on indigenous forests. A similar trend was observed for woodland and cropland between 2000 and 2005.

Figure 2: Land Cover in Navakholo May 1990

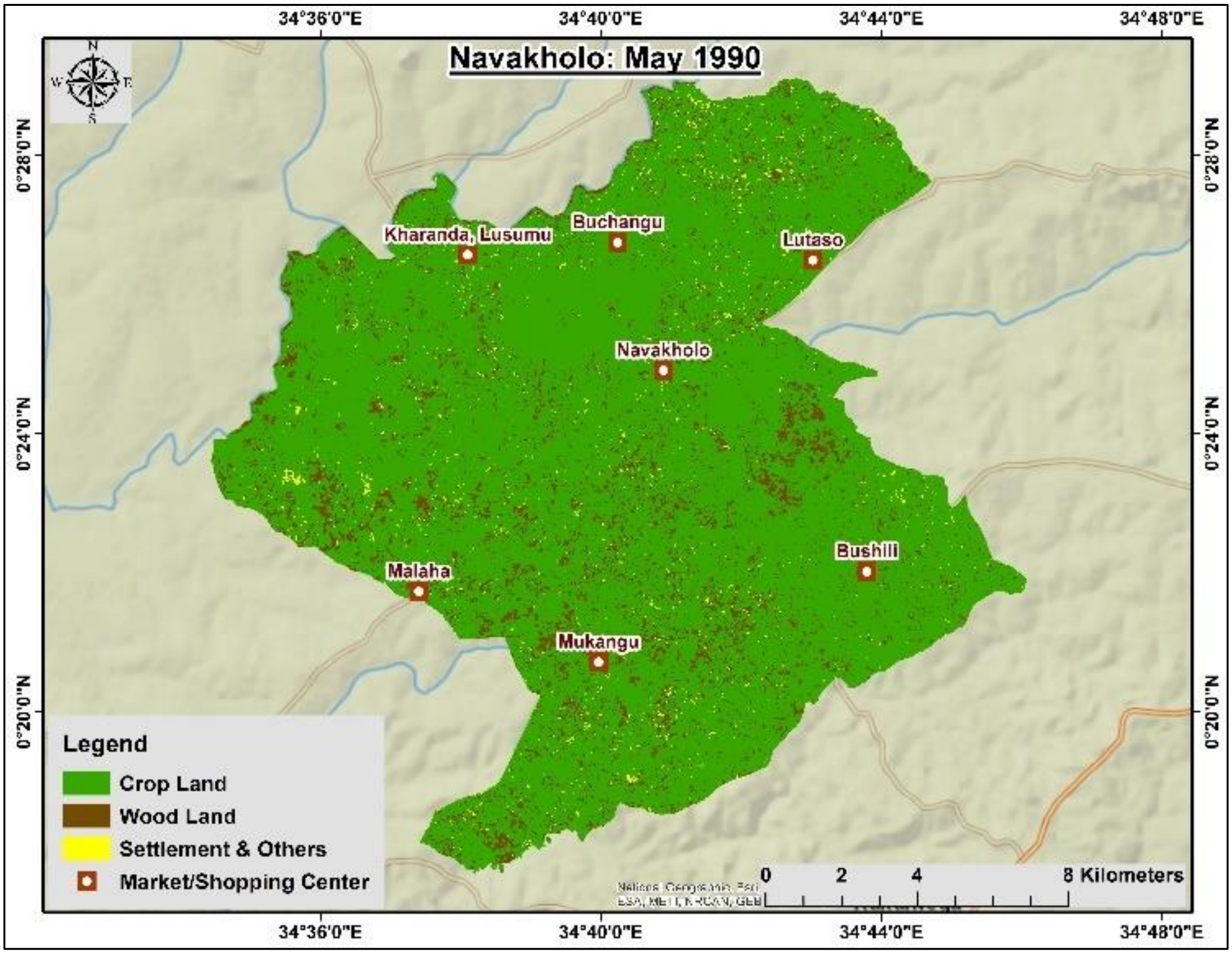

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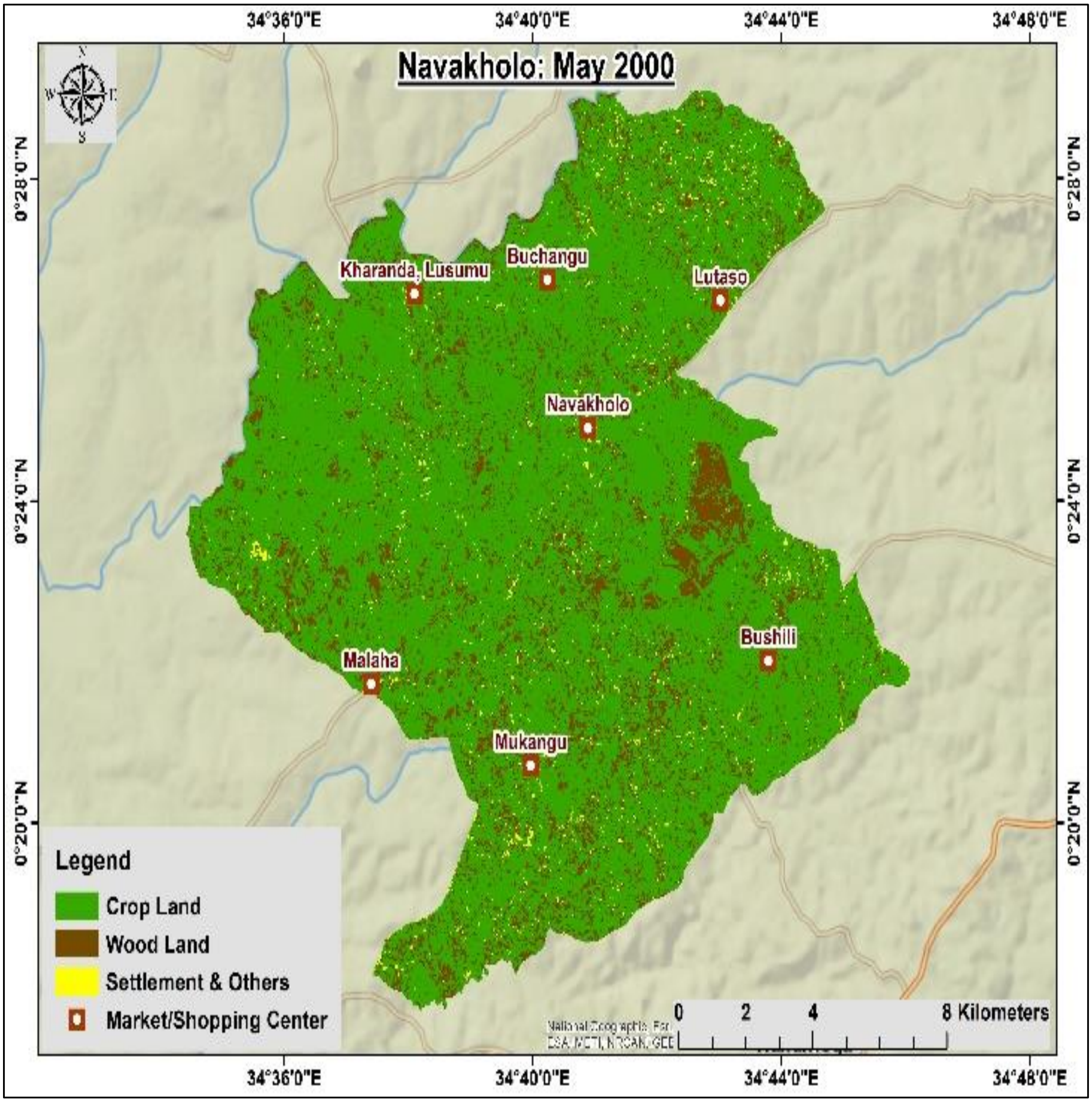
Figure 3: Land Cover in Navakholo May 2000



The year 2010 saw a slight decline in woodland (*Figure 4*). Area computation indicated that 4750.07 ha was covered by woodland. In 2015 there was a slight increase in the area covered by woodland. Area computation indicated that 4939.7 8 ha was covered by woodland. There has been an overall decline in woodland at 12.02% in Navakholo from 1990 – 2020 (*Table 2*). On the other hand, there has been an unprecedented rise in built-up areas and subdivisions of land by emerging families. This can be attributed to the increase in the human population that needs space for roads, schools, houses, and more land to cultivate. This would however pose a challenge when it comes to the availability of firewood for domestic energy requirements.

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Figure 4: Land Cover Navakholo May 2010

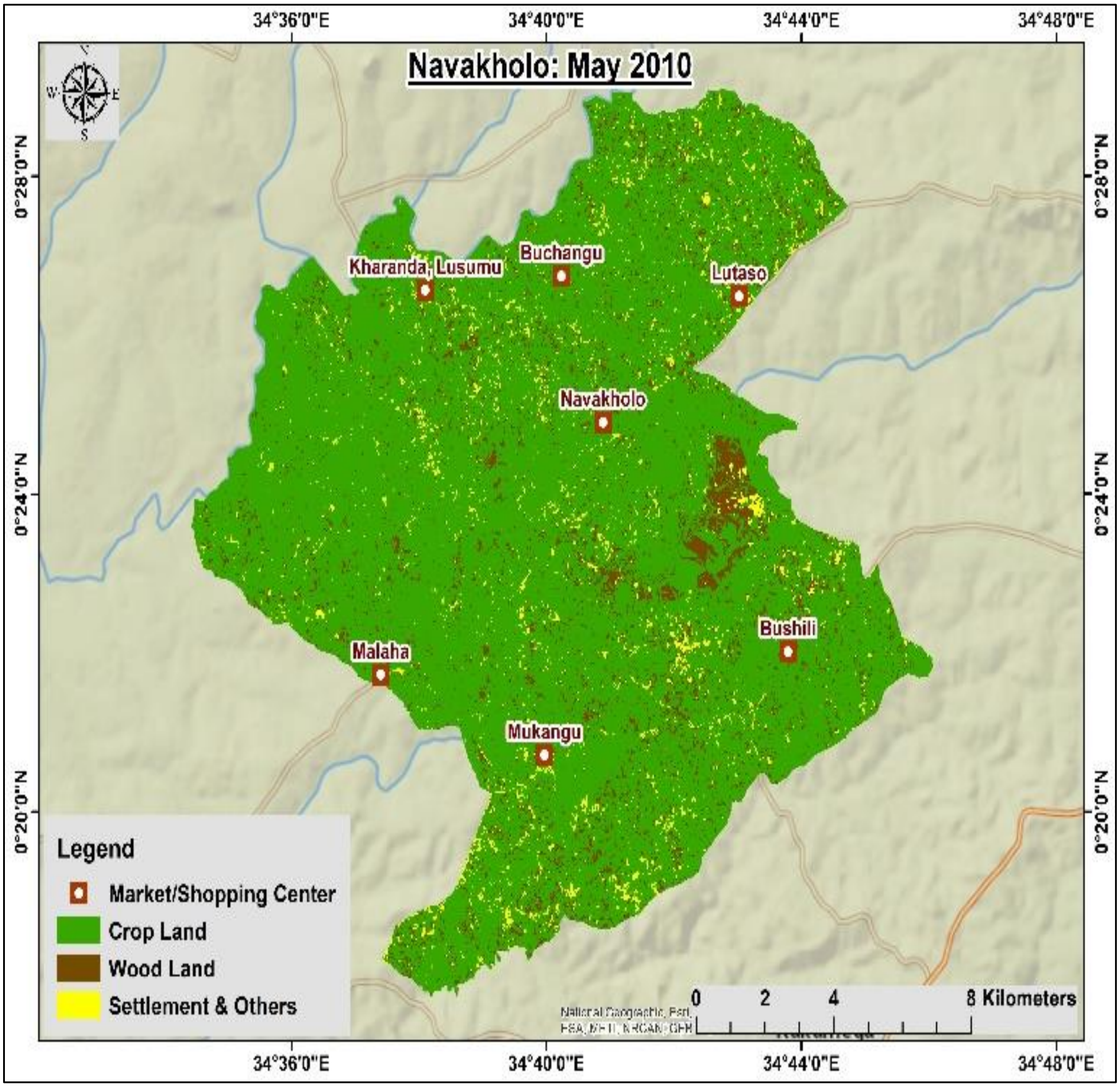

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Figure 5: Land Cover in Navakholo May 2020

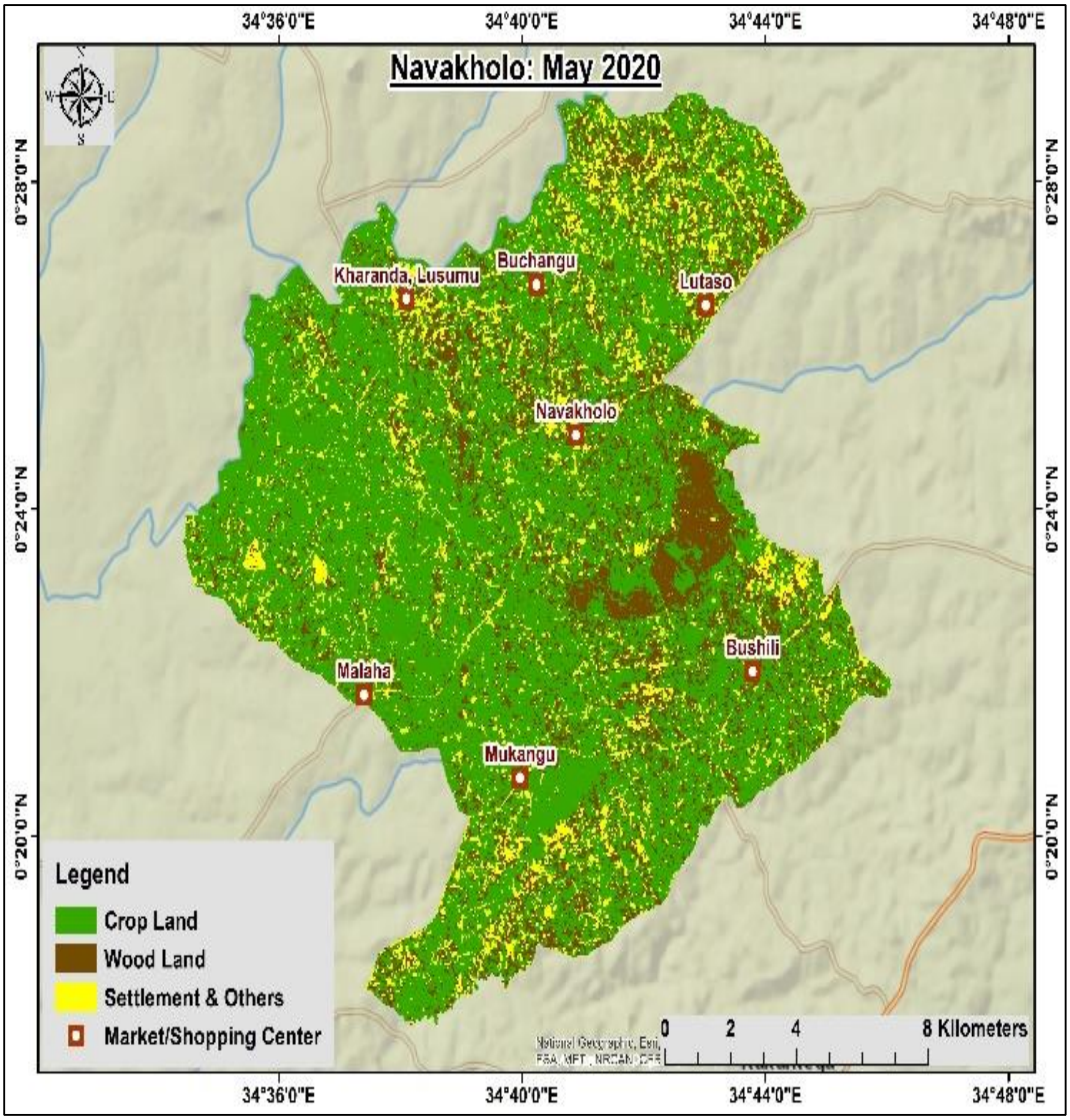

Table 2: Trends in land use changes from (1990-2020) in hectares (Nearest whole number)

	1990	1995	2000	2005	2010	2015	2020	% Net change
Cropland	19,514	19,518	19,450	19,249	19,227	18,844	17,232	-11.69
Woodland	5,690	5,196	5,013	4,864	4,750	4,940	5,006	-12.02
Settlement and other land uses	696	1,187	1,437	1,787	1,923	2,116	3,662	425.87

There has been an overall decline in cropland in the period covering 1990-2020 (*Table 2*). A similar decline in woodland was observed in 1990-2010, and in 2015 a slight increase in tree cover was observed. Since 2015 there have been efforts to improve the area under woodland coverage. The overall decline in the two land use classes is attributed to an increase in the area under the settlement. This is due to an increasing population that needs more land for their houses, roads, etc. The

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increase in settlements has led to increased land subdivisions, thereby competing with other land uses. Households rely on biomass, particularly fuelwood, to sustain their energy needs. Most of this fuelwood is derived from trees which have been reported to be declining. This has implications for the availability of biomass as demand outstrips supply. It is also an opportunity to promote the use of alternative fuel options to reduce the heavy dependence on fuelwood as a source of energy. There should be efforts to ensure a sustainable supply of fuelwood through proper management of woodlands and woodlots.

A growth spurt in population that is largely dependent on the declining biomass continues to create even more pressure on biomass. This will result in a decline in tree and forest cover. Increasing tree cover and the development of a sustainable supply of fuelwood is thus imperative going forward. This will enhance the availability and accessibility of biomass. It is, therefore, imperative that efforts go towards the introduction of trees in farms in order to enhance the availability of wood fuel. Conservation of forested areas, re-afforestation and afforestation practices will contribute to increasing the share of tree cover within the sub-county (Mugo & Gathui, 2010). The government, through the Kenya Forest Service, is committed to achieving 10% tree cover in the country (Netondo et al., 2010).

Based on the 2020 findings, cropland accounted for a significant percentage of land in Navakholo Sub-County (67%), while woodland, settlement, and other land use activities accounted for 19% and 14%, respectively. Opportunities for increased tree cover lies in agroforestry system and practices that blend with cropland. Attention is being paid to integrated farming systems involving different components of agroforestry such as forest and fruit trees, plantation crops, cereal and pulse crops, medicinal and aromatic crops, depending on the situation and requirement of the farmer (Dagar & Tewari, 2017). For example, fruit tree species of citrus, *Psidium guajava* are preferred along with cereal crops. Tree cover on agricultural land has the potential to contribute to climate mitigation (Zomer et al., 2016).

Table 3: Trends in tree/forest cover in Navakholo constituency 1990-2020

Year	% Cover	%Net change
1990	21.97	
1995	20.06	-1.91
2000	19.35	-0.71
2005	18.78	-0.57
2010	18.34	-0.44
2015.	19.07	0.73
2020	19.33	0.26

Source: Landsat 1-5,7, 8, Kenya Land Cover Survey and KU GIS lab

The decrease in tree/forest cover in *Table 3* shows an increase in human settlements has a negative implication on access to biomass as demand surpasses supply. This will lead to challenges in the access and availability of biomass energy options. There have been efforts to increase tree cover from the year 2015, but this does not correspond to the increasing level of growth of human settlements. Therefore, other measures to address the increasing demand for fuel need to be incorporated including value addition to biomass and the use of affordable alternative fuels. The decline in tree cover between 1990-2010 is attributed to the expansion of settlements through built-up areas and converting woodland into agricultural and other uses. The increase in woodland area from 2015 was attributed to increased tree planting activities as a response to positive environmental campaigns. However, due to

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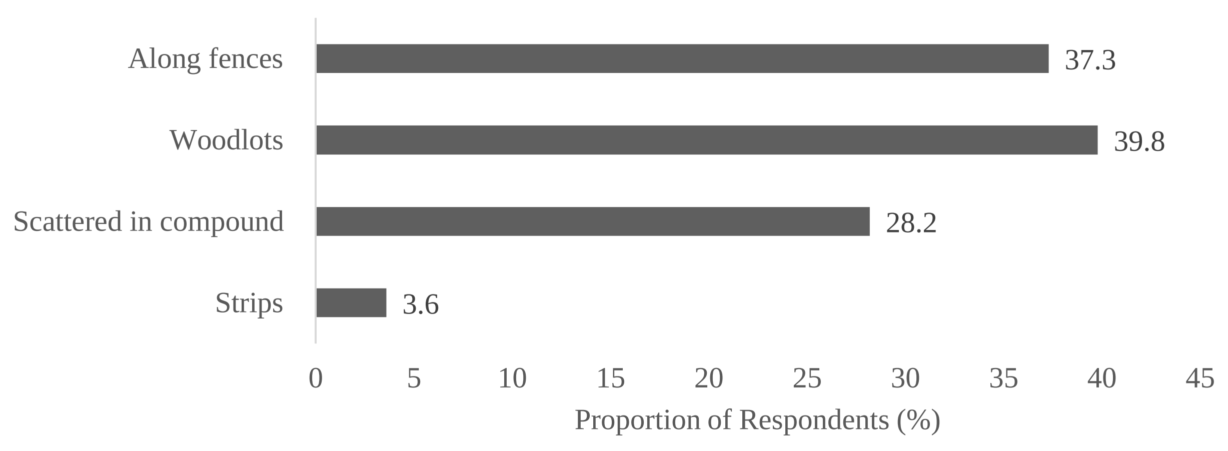
the expected natural increase in population and demand for settlement, appropriate management of the area under woodlands through afforestation and reforestation efforts may be implemented in the study area. In addition to this, expanding the area under woodlands and woodlots enhances tree cover. This will be achieved through better management of our protected areas, integrated farming systems to adequately use the available land and proper planning of the expanding settlements.

The environmental checklist showed that the majority of the households had trees either in the form of woodlots or planted along the fence. Firewood was used for cooking. Most of the respondents (78.9%) indicated that they had adequate tree cover. This was observed by the presence of trees and woodlots in the homesteads.

Figure 6: Tree cover practices among households



Woodlots occupied 39.8% of the tree cover patterns within the homesteads, followed by trees planted along fences at 37.3% (*Figure 6*). Trees planted along the fence were used to mark boundaries, while trees planted in woodlots, particularly eucalyptus, were mainly for commercial purposes. Although eucalyptus is prohibited within riparian areas in Kenya, its ability to sprout profusely makes it a good source of wood fuel for domestic energy security. Land use planning at the household needs to integrate this tree among other species for this purpose and manage it in ways that enhance wider livelihood and environmental benefits. A study in Ethiopia on carbon content in agroforestry practices showed that woodlots had significantly higher above-ground tree carbon, total tree biomass carbon, and total carbon, followed by home gardens and parklands (Bajigo et al., 2015). Woodlots have advantages including the fact that they require little land and labour, e.g., weeding is only necessary during early growth; furthermore, many trees receive no cash inputs or only minimal amounts for the purchase of seeds or seedlings as compared to other agroforestry practices (Kiptot & Franzel, 2011). With the availability of woodlots, respondents did not have to go far to access firewood. Access to fuelwood from neighbouring farms was hampered by the fact that one had to seek permission to access fuelwood; therefore, it depended on the relationship one had with their neighbours. Tree growing on farms has been acknowledged as a fundamental source of wood in the country (Ministry of Environment, Water and Natural Resources, 2013). Dynamic management of woodlots with early maturing tree varieties with the ability to sprout upon harvesting provides the way forward for household energy security.

Status of Biomass Energy Options and Their Relative Importance

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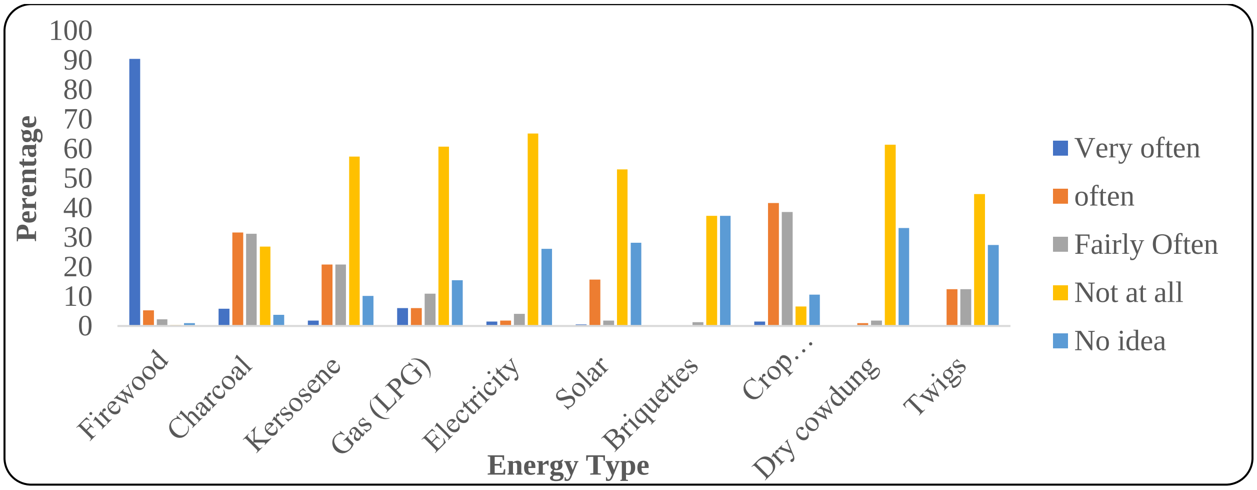
Firewood was the most popular energy source that was used very often at 90.4%, as expected for rural farming households, followed by crop residue (often used by 41.6%), followed by charcoal, which was used often at 31.7% (*Figure 7*). This is in line with studies on charcoal and firewood that state that charcoal is predominantly used in urban areas as opposed to rural areas (Sepp, 2014). Use of forest biomass for charcoal making could be a threat to the future of these resources, especially where there is high demand and a lack of proper forest management practices and regulations (Girard, 2002). Banning the sale and transportation of charcoal, as is currently the case in Kitui County, and a nationwide logging moratorium could be counter-productive as bans do not infact, reduce production but drive producers underground (Gonzalez, 2020). Thus there is a need for sustainable charcoal production through the use of energy-efficient kilns.

Figure 7: Use of energy types in households



Firewood was most popular because it's easily available and has been used over the years. To balance between the expected increased demand for firewood and maintenance of envisaged trees and forest cover, innovative tree stewardship in households is inevitable. Tree stewardship at the household level involves planting and nurturing the trees such that they are able to grow to their full potential, collecting dry branches and pruning as opposed to cutting down the whole tree to reap maximum benefits from the trees, growing trees that serve different purposes such that trees are able to effectively compete with other conflicting uses within the farm. Value addition in terms of using a by-product of wood such as sawdust, creation of briquettes and use of energy-efficient stoves.

According to the study, crop residues included the use of maize cobs and straws. Among the households, 41.6% used crop residues often, while 38.6% used crop residues fairly often (*Figure 7*). This shows that crop residues are also quite popular within households. They are used when there is a scarcity of fuelwood, thereby reducing pressure on tree cover. Maize cobs are used as a component of briquette production, thereby adding value, though this does not happen in Navakholo. This concurs with a study on crop use as a potential energy source that stated that crop residues could meet 50% of Malawi's energy demand (Gondwe *et al.*, 2017; African Renewable Energy, 2014)).

According to the study, 59.4% stated that they had not used briquettes. These statistics point to a glaring gap in regard to knowledge and perception of briquettes as a source of energy within the household. Briquettes have not been widely adopted in developing countries due to the high cost of production, lack of awareness of their sustainability, lack of ready market and poor packaging and

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distribution systems for the product (Emerhi, 2011). Respondents were asked if they used dry cow dung as an energy source. Up to 61.4% did not use cow dung at all, and 33.2% had no idea of the use of cow dung for energy (*Figure 7*). A study in India showed that households relied on a combination of dung cakes (flat disks of dried cow dung approximately ten centimetres in diameter) and fuelwood for cooking and use of a traditional clay stove known as 'chulha' (Stockholm Environment Institute, 2012). The dung cakes were made in the cooler months, whereby wet dung from buffalo is gathered, shaped by hand into cakes and left to dry for three to seven days and then stored in communal spaces. During cooking, dung cakes are broken up by hand and fed into the fire. According to SEI (2012), dung cakes create a significant amount of smoke when its first lit, but once it's burning, the smoke subsides. The dung does not burn as hot as wood and is used for purposes such as boiling milk. Further, the majority of the households, 44.7%, did not use twigs at all, while 27.4% had no idea about the use of twigs as a source of energy in the household (*Figure 7*). This is explained by the fact that twigs are used in combination with other fuel sources, and it was not as effective as fuelwood. Therefore, the use of twigs does not reduce pressure on tree cover. However, up to 12.4% of the respondents agreed to use twigs often as a source of fuel. The results show that the use of twigs is not very popular in households.

Firewood, charcoal, and crop residues are relied upon to cater for energy sources within the household. This is due to their availability. Briquettes were not popularly used due to a lack of technical know-how on how to produce them. Cow dung was not used as it is viewed as archaic. This shows that households in Navakholo heavily rely on biomass to cater to their energy needs.

Table 4: Mean rating of household access to biomass-based energy options

	N	Mean	Std. Dev	Std. Error Mean
Briquettes	386	1.63	0.509	0.026
Cow dung	384	1.70	0.976	0.028
Twigs	388	2.15	1.015	0.052
Charcoal	392	3.09	0.985	0.050
Crop residue (cobs, straw)	390	3.17	0.976	0.049
Firewood	391	4.86	0.550	0.28

Table 5: Testing mean access to Biomass energy sources

	Test Value = 2					
	t	Df	Sig. (2-tailed)	Mean Difference	95% CI of the Difference	
					Lower	Upper
Firewood	102.706	390	0.000	2.857	2.80	2.91
Charcoal	21.853	391	0.000	1.087	0.99	1.18
Crop residue	23.649	389	0.000	1.169	1.07	1.27
Twigs	2.851	387	0.005	0.147	0.05	0.25
Briquettes	-14.199	385	0.000	-0.368	-0.42	-0.32
Cow dung	-10.622	383	0.000	-0.302	-0.36	-0.25

The mean rating of respondents' access to biomass-based energy ranged from 1.63 to 4.86 on a five-point Likert scale (*Table 4*). This implies that an average individual from the sampled population is likely to be accessing firewood very often (4.86 = 5 on the Likert scale). Access to charcoal (3.09 = 3 on the Likert scale) and crop residue (3.17= 3 on the Likert scale) by an average individual from the sampled population is rated fairly often. However, twigs (2.15 = 2 on the Likert scale), briquettes

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(1.63= 2 on the Likert scale), and cow dung (1.7 = 2 on the Likert scale) are not used by an average resident of Navakholo Sub-County. Twigs are not used as a fuel option in the household because of the long time it takes to gather the twigs and also in the event that you light the fire, longevity is not guaranteed. Respondents did not use briquettes as they were not aware of their use and the fact that they were not easily available.

The mean access to firewood, charcoal, crop residue, and twigs was significantly different from 2 (Not used at all) as hypothesised (*Table 4*). Further, the respondents' access to biomass energy sources had p-values of p=.000. (*Table 5*). This means that an average resident rated their access to the different sources of biomass above 2 (Not used), except for briquettes and cow dung. As shown above, 2 on the Likert scale implies zero access to the energy resource. Therefore, residents were accessing firewood, charcoal, crop residues and twigs. Therefore, the null hypothesis that farm households in Kakamega County do not access quality biomass-based energy is rejected.

Relationship between Tree and Forest Cover and Preference of Energy Option

A relationship between forest cover and the preferred energy option was established using Pearson correlation tested at $P \leq 0.05$. In homesteads where residents often preferred firewood, there was significantly no appropriate tree cover ($r = 0.104$, $P = 0.040$). In homesteads where residents often preferred charcoal, gas, electricity, briquettes, cow dung or twigs, tree cover was rated as appropriate ($P < 0.05$) (*Table 6*). Charcoal is normally purchased or acquired from sources outside the home, which also indicates the need for households having some kind of income security. To sustain this income flow, trees planted within the home were used for other commercial purposes not necessarily to cater for energy needs within the household.

Table 6: Relationship between appropriate tree cover and preference of energy option

		Does your homestead have an appreciable tree cover
Firewood	R-value	0.104*
	Sig. (2-tailed)	0.040
Charcoal	R-value	-0.282**
	Sig. (2-tailed)	0.000
Kerosene	R-value	-0.073
	Sig. (2-tailed)	0.154
Gas	R-value	-0.152**
	Sig. (2-tailed)	.003
Electricity	R-value	-.154**
	Sig. (2-tailed)	0.002
Solar	R-value	-0.099
	Sig. (2-tailed)	0.051
Briquettes	R-value	-0.201**
	Sig. (2-tailed)	0.000
Crop residue, e.g., cobs	R-value	-0.024
	Sig. (2-tailed)	0.632
Cow dung	R-value	-0.196**
	Sig. (2-tailed)	0.000
Twigs	R-value	-0.161**
	Sig. (2-tailed)	0.001
	N	389

Responses to Potential Firewood Crisis

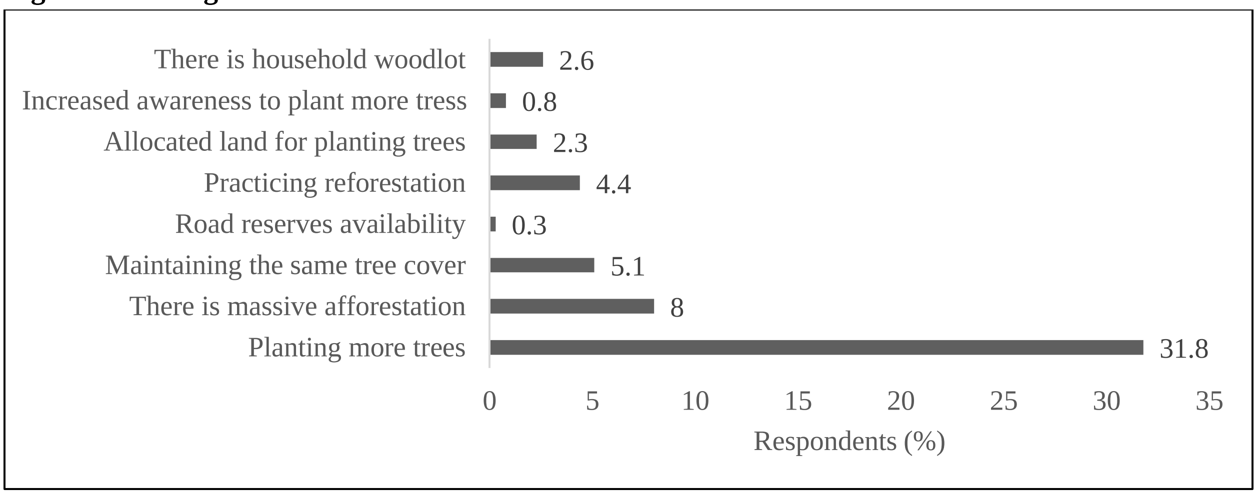
When there is a total lack of firewood in a homestead, most of the residents (40.6%) indicated that they would switch to the use of kerosene with gas (24.9%) and solar energy (*Table 7*). The affordability of these energy sources would still be a challenge to many households due to their initial high investment cost.

Table 7. Residents fall back on energy sources when there is a total lack of firewood

Fallback energy source	Frequency (N = 394)	Percentage
Kerosene	160	40.6
Gas	98	24.9
Solar	49	12.4
Electricity	14	3.6
Biogas	2	0.5
Non-committal	71	18.0

In this regard, deliberate efforts to increase tree cover should merit serious consideration at the household level, as shown in respondent options in *Figure 8*. Planted trees would then require certain management practices to prolong their life and thus guarantee the availability of fuelwood (*Figure 9*).

Figure 8: Strategies to enhance tree cover



To ensure a continuous supply of charcoal, the residents mainly sell specific weights, practice regular tree planting, and extinguish fires after cooking. For continuity of supply of sawdust, they ensure dry storage (13.3%) and extinguish fire after cooking. These practices were also noted for the management of firewood, where most of the residents (66.7%) practice regular planting of trees. Pollarding (60%), coppicing (53.3%), dry storage (63.35%), and selling of specific weights (63.3%) were strategies used to ensure continuous supply (*Table 8*). Pollarding and coppicing of trees were practised to enhance the continuous supply of firewood among households. Pollarding is a pruning system which involves the removal of the upper branches of a tree, which promotes the growth of a dense head of foliage and branches. This leads to early harvest of wood, fodder or other biomass. A study in Ghana showed that rural households used coppicing where planted or harvested trees are harvested stump high to allow for fast sprouting and harvesting of branches of live trees (Amoah et al.,

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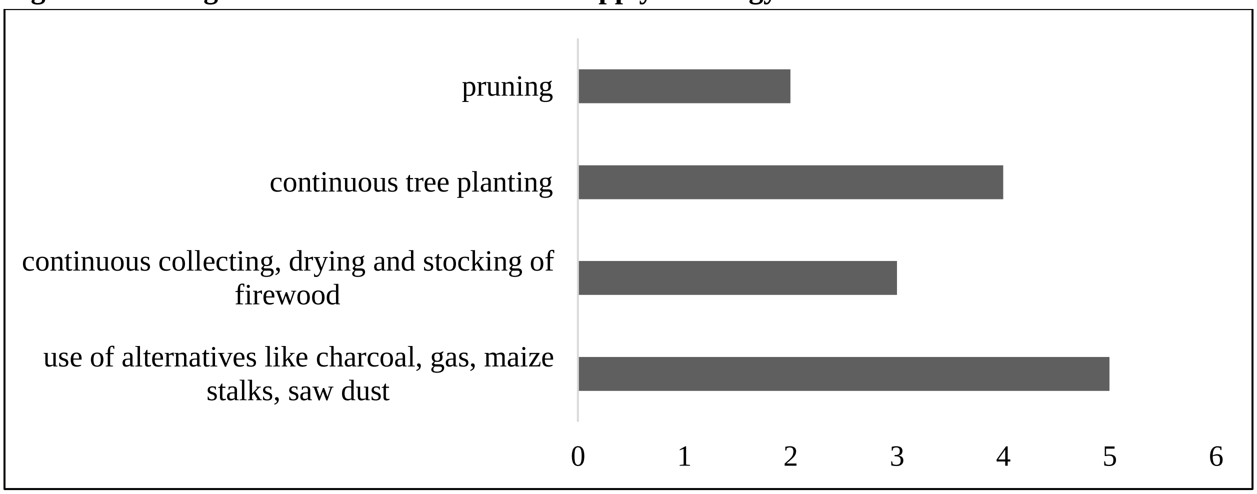
2015). These strategies have been found useful as firewood can be periodically collected from the same stand.

Table 8: Management of biomass for continuous supply

	Firewood	Biomass	Briquettes	Husks	Dung	Saw dust	Charcoal dust
Pollarding	18 (60.0%)		-	-		-	3 (10.0%)
Coppicing	16 (53.3%)	-	-	-	-	-	2 (6.7%)
Pruning	16 (53.3%)	-	-	-	-	-	1 (3.3%0
Regular replanting	20(66.7%)	-	-	-	-	-	6 (20.0%)
Dry storage	19(63.35)	-	-	-	-	4 (13.3%)	5 (16.7%)
Chopping to fit	17(56.7%)	--	-	-	-	-	1 (3.3%)
Extinguishing after cooking	8 (26.7%)	-	-	-	-	2 (6.7%)	6(20.0%)
Selling specific weights	19(63.3%)	-	-	-	-	1(3.3%)	8(26.7%)

Figure 9: Strategies to ensure the continuous supply of energy for domestic use



According to FGDs carried out within the wards in Navakholo, strategies to ensure continuous energy supply include the use of alternatives such as charcoal, sawdust, maise cobs and stalks, sugarcane stalks, continuous tree planting, continuous collecting, drying, and stocking of firewood and pruning (*Figure 9*). Other measures include the use of energy-saving *jikos* and pressure cooker; avoiding frequently cooking food that requires more energy to cook, and use of Improved Cooking Stove (ICS); the planting of fast-growing species that are suitable for firewood; harvesting and preserving wood through drying and stocking in advance. The management of firewood within the household involves value-additional strategies such as drying and storage for future use. Pruning is also used to increase the availability of wood. Alternative energy types are used to substitute the available fuelwood. This is useful in reducing the high dependency on fuelwood as a source of fuel.

The tree planting initiatives in Navakholo Sub-County may not be able to address the increasing demand for biomass. Therefore, there is a need to scale up tree planting in order to sustain future fuelwood supply. Management of household woodlots is critical to enhancing fuel wood supply.

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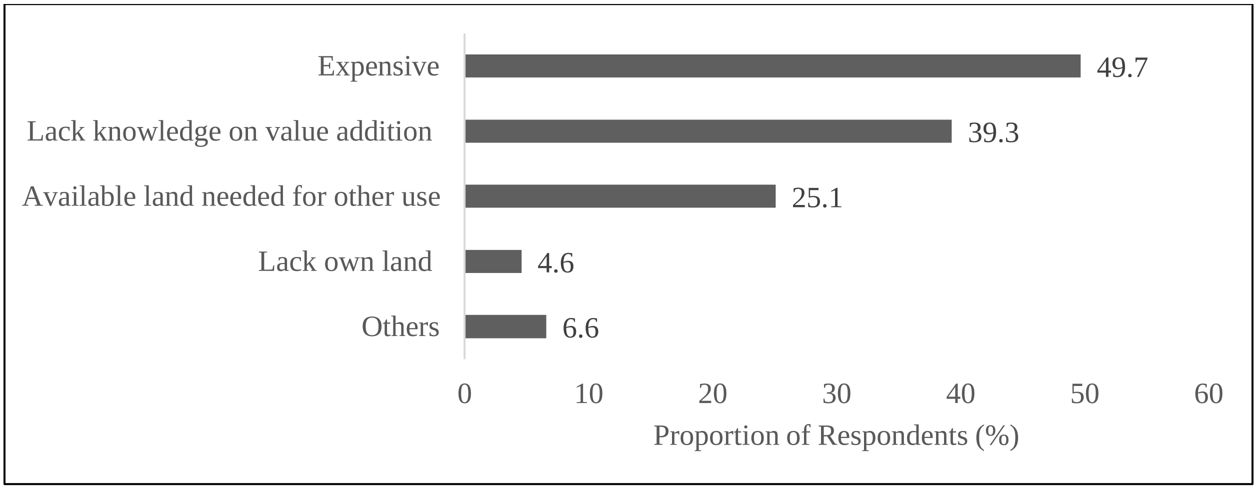
Declining tree cover could be attributed to increased demand for wood products, encroachment of forested areas and conversion to other land uses and land tenure. Decreasing land available for trees is due to the increasing population and the competing land uses such as agriculture and settlements that are taking over available land, thereby leading to inadequate wood fuel supply. This is in line with a study on fuel consumption in Nigeria that stated that the depletion of forests and harvesting of trees and shrubs for biomass are the reasons for fuelwood inadequacy (Momodu, 2013).

Challenges and Opportunities in the use of other Biomass Options

A total of 83.5% of those interviewed found it difficult to invest in biomass energy. High expenses were identified as the main obstacle, while not having own land was the least hindrance (*Figure 10*). Expenses (49.7%) are a challenge due to the initial capital needed to invest in these solutions. Lack of knowledge on value addition (39.3%) is a challenge as respondents were familiar with age-old practices of using firewood. There were few if any, value-addition initiatives. Such initiatives include the production of briquettes which was not easily adopted among households. This could be attributed to the cultural significance of using firewood and the lack of awareness of the benefits of value-added fuels. Biogas is perceived as expensive due to the high installation costs associated with its use and a lack of awareness of its use. The use of briquettes was a challenge due to the lack of technical know-how of its production. For biofuels, there is not much awareness of crops for biofuel production.

Available land needed for other uses was a challenge due to the competing needs and uses for the available land. With the rising population, most of the land has been set aside for settlement, and the rest has been used as cropland. There remains a challenge as to whether to put available land under agricultural uses or grow plantations for the production of biomass. Lack of own land remains a challenge of investing in biomass. This is attributed to land tenure issues. A 2012 review of Household Clean Energy Technologies in Kenya and Tanzania by the Africa Biodiversity Collaborative Group, USAID, GVEP concluded that lack of financing by the consumer and cultural reluctance to change were major constraints to investing in biomass energy solutions (Clough, 2012). If the cost of investment in biomass energy solutions continues to be a challenge, value addition for popular biomass energy sources should be encouraged.

Figure 10: Reasons for not investing in biomass energy solutions



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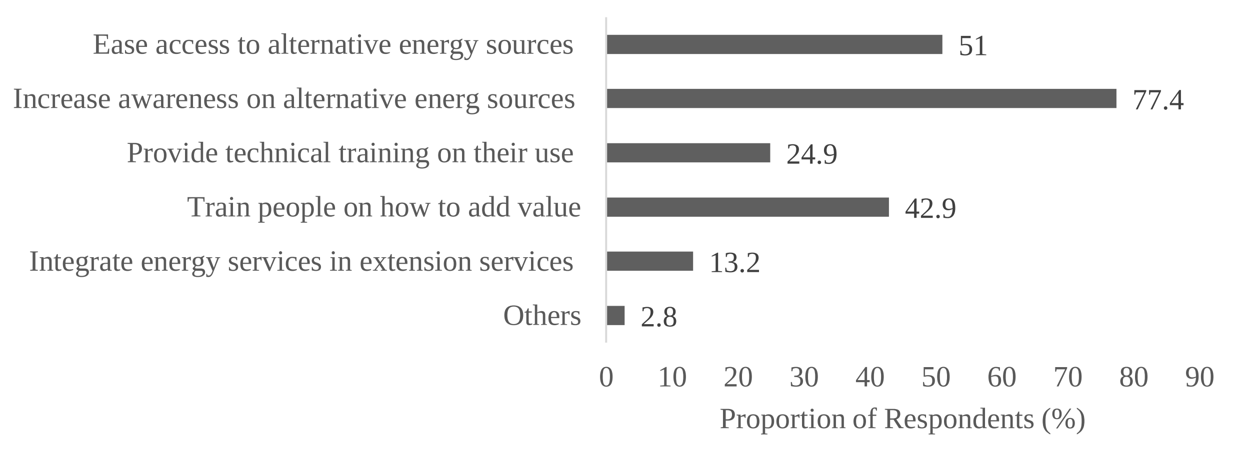
In order to invest in clean energy alternatives, most respondents (77.4%) indicated the need to create awareness of their benefits. Ease of access to alternative energy sources was identified by 51% of the respondents while training in value-addition was proposed by 42.9% of the respondents (*Figure 11*). Awareness creation on the use of alternative sources is critical to reducing overreliance on biomass, specifically, on the benefits of gas and solar as clean, safe, and efficient energy sources that do not cause harm to the environment. Ease of access to alternative energy options should be promoted by the introduction of subsidies to address the challenges of initial capital requirements. Credit facilities can be provided to encourage the uptake of these energy sources. For example, the connection fee for electricity connection has been reduced to enhance connectivity to the grid. This is a good initiative to encourage the uptake of electricity as an energy option in households.

Value addition increases the market value of a product. In this case, solar packages have been introduced that serve as a source of fuel, have charging stations and offer lighting solutions for households. This way, the uptake of solar within households will increase. If people are trained in value addition, it could be a source of livelihood for those that deal in those products. Value addition also ensures efficiency, reduces wastage and is favourable to the environment. The design of appropriate products for the market, introduction of clean energy technologies, access to financing, education, information and awareness creation, and creation of favourable policies to develop the market enhances access to clean energy (Government of Kenya; United Nations Development Programme, 2016).

Figure 11: Facilitating households to invest in clean energy



CONCLUSIONS

Although there is a general decline in tree cover in the study area due to changing land use, the adequacy of fuelwood varies across households. Households which indicated having adequate tree cover attributed it to having secure woodlots and trees along fences, mostly exotic varieties that grew fast and matured early. Having appreciable tree cover in one’s compound did not, however, necessarily translate into the adequacy of fuelwood within the household. Trees in homes were used for other purposes other than supplying biomass energy. Decreased availability of wood fuel at household levels was attributed to the government’s restriction to protected forests, private property rights that restricted open harvesting and or collection of firewood, increase in activities that consumed bulk fuelwood such as brick-making and charcoal burning, clearing of tree cover to create

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room for settlement, limited planting of trees and commercial use of timber.

In cases of severe shortage of firewood, most of the residents preferred to use kerosene stoves. Overall, fuelwood remains the preferred energy source. It is declining availability was attributed to an increase in income generation activities that consume it in bulk, such as brick making and charcoal burning, clearing of trees to create room for settlement and commercial use of timber. The future of household energy security lies in afforestation practices that are suitable for declining land sizes and more efforts in promoting the use of other biomass energy options that reduce pressure on tree cover.

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Conflict of Interest Statement

The Authors confirm that there is no conflict of interest in this article

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